T18/B12/FRG6/94

IEA SOLAR HEATING AND COOLING PROGRAMME

TASK 18

ADVANCED GLAZING
AND
ASSOCIATED MATERIALS FOR SOLAR AND BUILDING APPLICATIONS

B12 Measurement of total energy transmittance of advanced glazing systems

Description of CALPLATE2, the new calorimeter at ISE for the determination of the total energy transmittance g

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General description

"CALPLATE2" is the second generation of an experimental indoor facility, based on an illuminated hot-plate equipped with heat flux meters and temperature sensors at different positions of an absorber plate. Its aim is to determine the total energy transmittance g for transparent glazing systems or collector covers for variable incidence angle of the incoming radiation from the solar simulator. The measurement may be done at 11 selected positions to determine local effects such as edge effects and local convection coefficients. The system is contained in an insulated cabin, which is air-conditioned. The solar simulator for the sample size of maximal 1000 mm x 1200 mm consist of four 2.5 kW halogen-metal lamp within a reflector-array. The energy is collected by a thermostatically controlled black absorber plate covered with a layer incorporating a heat flux sensor plate and temperature sensors to measure the net heat flux into the absorber and the surface temperature (see fig. 1).

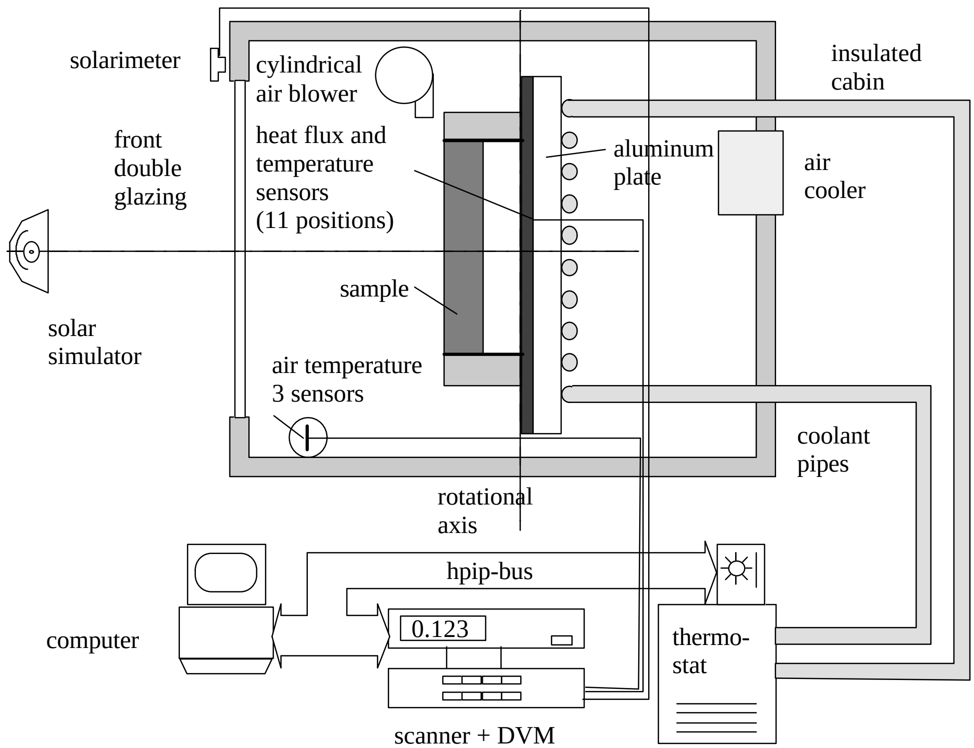

Fig 1: Schematical setup of calorimetric device

The test method is based on the measurement of the energy collected by the absorber behind the sample in a steady state condition. The energy balance equation then is:

$$q_{net} = g(q) \cdot I - \frac{T_{abs} - T_{amb}}{R_{cover}} \qquad (1)$$

where the thermal resistance of the complete cover R_{cover} consists of three parts: the resistance R_{gap} from the absorber surface to the inner sample surface, the resistance R_{sample} and the external surface resistance to the ambient R_a. R_{sample} may be determined - depending on the temperature - in a heat plate apparatus first, but also in the calorimeter without irradiation (dark mode). The internal gap resistance R_{gap} is dependent on the gap width (from 0 to 30mm typically), on the convection within the gap and on the bounding surface emissivities. The external resistance R_a is mainly influenced by the convection at the sample surface and by the sample emissivity. Approximately the value of R_{cover} may be determined by calculation (using R_{sample}) or by a separate dark measurement (without illumination). In practice the temperature difference T_{abs}-T_{amb} is kept small in order to reduce the influence of ΔR_{cover}.

The value of g is then derived from eqn. (1) from the measured values of I, T_{abs}, T_{amb} and q_{net}.It is possible to vary the incidence angle θ for the radiation between -60° and +60° by rotating the absorber plate and the sample on a vertical axis.

Light source

The solar simulator used has a four reflector units with one horizontal 2.5 kW OSRAM HMI halogen-metal bulb in each unit. The spectrum given by the manufacturer resembles closely the CIE AM1.5 spectrum listed in the CIE 85. The spectrum is shown in figure 2.
The main problems are the divergence and the homogeneity of the illumination. An area of 1000mm x 1000mm may be illuminated with deviations of less than ±5 percent around the average.The divergence of the source has to be quantified in future investigations. Figure 3 shows a measured scan of the irradiation intensity as measured in the absorber plane with a solarimeter (Kipp&Zonen CM11).

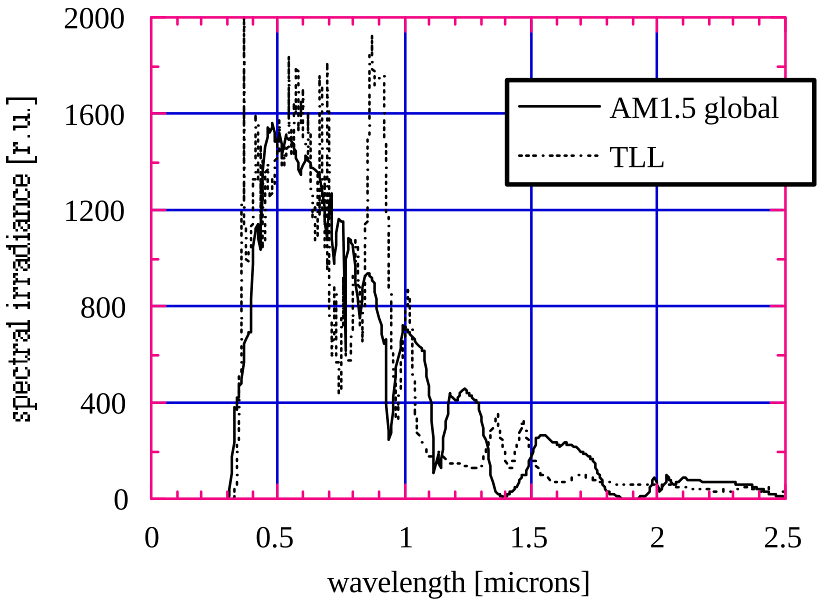

Fig. 2: Spectral distribution of the HMI simulator compared with CIE Am1.5 spectrum (spectra not yet correct)

Measurement of the collected energy

The measurement of the heat flux q_{net} is done by 11 heat flux sensors imbedded in a sheet of the glas-fibre enforced resin (material used for heat flux sensor fabrication) behind a 2mm thick PMMA plate painted black (absorptivity α_95%). For every heat flux plate a PT-100 film temperature sensor is glued between sensor and plate and connected with 0.2mm thin wires. The complete sensor plate is mounted on an 10mm aluminum plate, whose temperature is controlled by a water thermostat. The backward part of the absorber plate is covered with an hydraulic loop. The temperature stability of the absorber surface is very good. Figure 4 gives a view of the sensor positions and dimensions on the absorber.

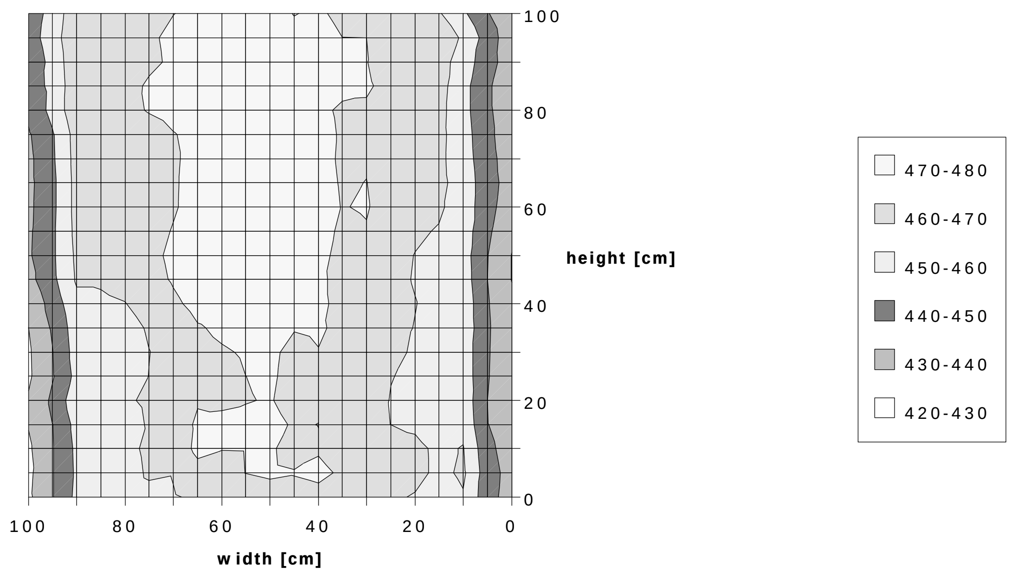

Fig. 3: Intensity distribution in the absorber plane (not yet optimized)

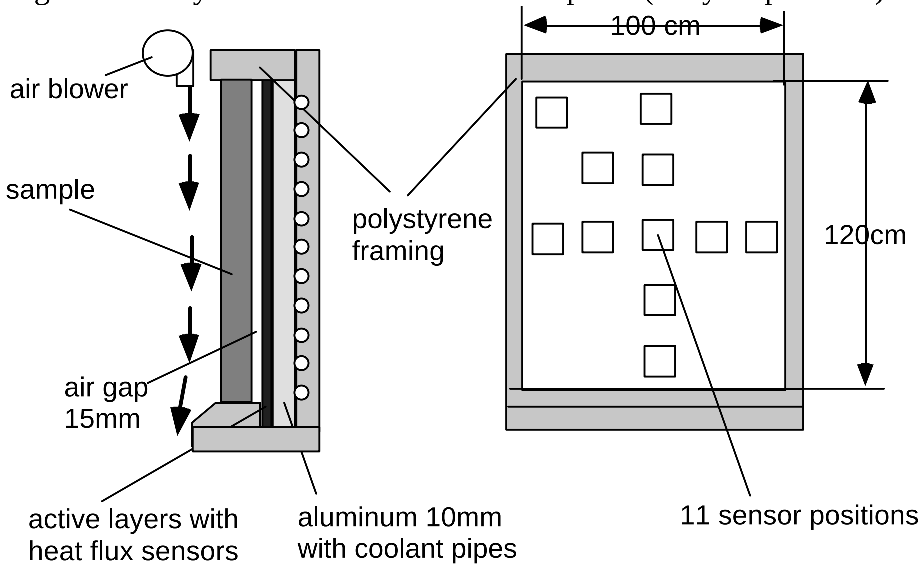

Fig. 4: Sensor positions on the absorber plate

As the PT-100 sensors do not measure the surface temperature of the absorber, but a value below the PMMA layer, the actual surface temperature is calculated by the measured heat flux and the experimentally determined thermal resistance from the surface to the sensor position.

The ambient air is ventilated by a cylindrical 1m long air blower. This avoids a stratification in the cabin and determines the external convective heat transfer coefficient. The blower operates at three stages with air speeds of about 4.5, 5.8 and 7.0 m/s. The corresponding total heat surface coefficients at the sensor locations have been determined experimetally and are shown for 7 m/s in figure 5. To control the degree of stratification three shaded PT-100 sensors measure the air temperature at the bottom, at the sample and at the top level of the cabin. In all the experiments the difference between these temperatures was smaller than one degree.

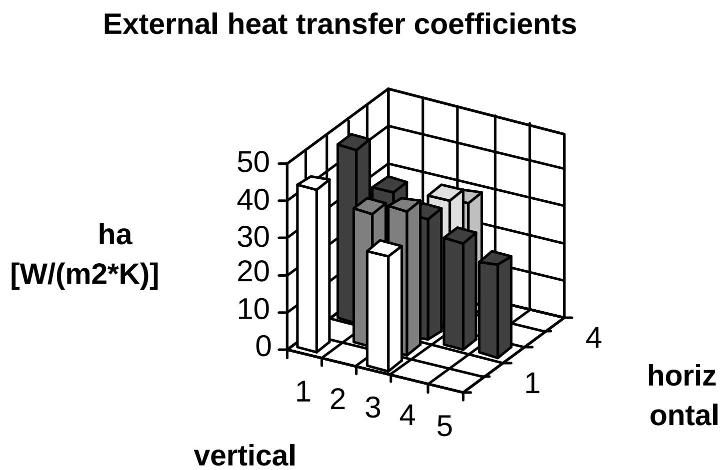

Fig. 5: External heat surface coefficients measured at the sensor positions

Future work

At the moment the heat flux sensors are being re-calibrated in situ using the calibration panels distributed within IEA Task 18 project B14. The calibration constants given by the certificates from the manufacturer may be changed to some extent due to the application in the absorber plate. Wind speeds and external surface coefficients have to be determined in more detail depending on the shape of the framing for the sample. The spectral distribution of the solar simulator might be dependent on the position and on the intensity. This has to be investigated with a spectral radiometer.
A possible improvement might be required if the temperature oscillations produced by the simple air cooler will proof to be too large.

Technical Details

Light source (existing):

Arc dimension	2mm x 20mm
Irradiation area	1000 mm x 1200 mm
Irradiation level	400 W/m^2 at 2.5m distance
Spectral distribution	Halogen-metal vapour lamp OSRAM HMI2500 close to AM1.5
Irradiation uniformity	better than 5% peak-to-average
Collimation	not yet known
Electric power	12 kW

Absorber plate (PMMA sheet with heat flux sensor layer on the back):

Area	1000mm x 1200mm
Active area (measurement)	11 positions within whole area
Coating	3M Nextel paint
vertical axis	variable distance to absorber plane (depending on sample thickness)

Cabin

ventilator	1m long axial air blower (3 speeds) variable distance to absorber plane
air-cooler	room cooler with simple On/Off controller
heat insulation	50mm polyurethane foam (non-transparent) low-iron double glazing (transparent)

Instrumentation:

Ambient temperature	3 shielded PT-100 sensors at different height, in cabin (no irradiation)
Heat flux meters	100mm x 100mm each, integrated in polymeric layer
temperature sensors	0.05mm thin film PT-100, integrated in polymeric layer
Solar irradiation	Kipp&Zonen CM11 Solarimeter above absorber plane (angular control), outside cabin (intensity monitoring) and on movable XY-scanner in absorber plane